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Science Communication

Learning to Write Like a Scientist: A Writing-Intensive Course for Microbiology/Health Science Students †

Kimi Grzyb[1], Wesley Snyder[2], and Katharine G. Field[3]*
[1]*Environmental Sciences Program, Oregon State University, Corvallis, OR 97331;*
[2]*Rhetoric Program, Oregon State University, Corvallis, OR 97331;*
[3]*Department of Microbiology, Oregon State University, Corvallis, OR 97331*

Learning the tools and conventions of expert communication in the sciences provides multiple benefits to bioscience students, yet often these skills are not formally taught. To address this need, we designed a writing-intensive microbiology course on emerging infectious diseases to provide upper-division students with science-specific writing skills along with disciplinary course content. The course followed the guidelines of our university's Writing Intensive Curriculum (WIC) program. Students wrote a press release, a case study, a controversy/position paper, and a grant prospectus, and revised drafts after feedback. To assess the course, in 2015 and 2016 we administered pre-post surveys and collected writing samples for analysis. Students reported on their experience, training, skills, and knowledge before taking the course. They then rated the extent to which the assignments, lectures, in-class activities, and writing activities contributed to their attainment of the learning outcomes of the course. Students entering the class were inexperienced in tools of science writing and the specific genres covered by the class. Their confidence levels rose in both skills and knowledge. Feedback from instructors was cited as most helpful in the majority of the areas where students reported the most gains. The survey provided evidence that discipline-specific knowledge had been acquired through writing activities. Teaching science writing by allowing the students to write "fiction" (e.g., a case report about a fictional patient) was effective in maintaining a high level of interest, both in learning the conventions of the genre and in seeking out detailed information about emerging infectious diseases. Both the course structure and the specific assignments would be useful at other institutions to teach science writing.

INTRODUCTION

Science writing and science communication have been identified as key competencies in biology education (1–5), yet often these skills are not formally taught. Few microbiology and biological/health sciences graduates entering graduate or professional programs will have had "conscious, systematic, discipline-specific writing instruction" (6, p. 18). At our university, a university-wide "Writing Intensive Curriculum" (WIC) program has been instituted to teach upper-division students how to write within their specific disciplines. Here we describe and evaluate a WIC microbiology course designed to teach science writing skills to students majoring in Microbiology, Biology, and BioHealth Sciences.

There are compelling reasons to teach discipline-specific writing to bioscience students. There is a strong connection between undergraduate experience in "real-world" research and writing, and perceived self-efficacy and student identity (7–10). In addition, writing science improves students' ability to understand primary literature (2), think critically (11), and communicate science (2). Yet science faculty commonly underestimate the need for formally teaching writing skills to science majors. Most trained scientists and researchers gradually learned the writing conventions and genres of their trade during the process of their own training (12). Because they learned science writing on their own, writing conventions and genres may appear "transparent" (12), and the need for formally teaching these skills to students may not be apparent. Faculty may also assume that writing skills learned in basic writing courses are easily transferred to more advanced, discipline-specific writing (13). This assumption ignores the variety of conventions and expectations that are highly specific to each discipline. Furthermore, students may not transfer skills learned in basic composition courses to discipline-specific contexts (14). Research suggests that discipline-specific writing is best taught by members of that discipline (15, 16).

*Corresponding author. Mailing address: Department of Microbiology, 226 Nash Hall, Oregon State University, Corvallis, OR 97331. Phone: 541-737-1837. Fax: 541-737-0496.
E-mail: kate.field@oregonstate.edu.
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To address this need, we developed a writing intensive course aimed at juniors and seniors. The third and fourth times we taught the course, spring quarters 2015 and 2016, we administered pre-post surveys and collected writing samples for analysis. Students reported on their experience, training, skills, and knowledge before taking the course. They then rated the extent to which the assignments, lectures, in-class activities, and writing activities contributed to their attainment of the learning outcomes of the course. Our objective was to assess the overall success of the course and the effectiveness of each of the course elements.

METHODS

Course design

The course follows the guidelines of our university's "Writing Intensive Curriculum" (WIC) program. All students at our university must take a WIC course within their major department, in addition to Writing I (Composition) and Writing II. WIC courses go through a stringent approval process: they must be upper division, have both disciplinary course content and writing content, be at least three credits, be taught by faculty in the discipline, have a student to instructor ratio no greater than 20 (counting graduate teaching assistants), use minimally-graded writing as a mode of learning course content, and use formal writing assignments to provide students with experience writing in genres and using conventions pertinent to the discipline. Students must be able to revise drafts after feedback. Three university-wide WIC-relevant learning outcomes are added to course learning outcomes (Table 1).

TABLE 1.
MB/BI 385 learning outcomes.

1.	Explain the germ theory of disease and the discovery of infectious agents.
2.	Demonstrate an understanding of the scientific method (including acquisition and integration of knowledge through observation and experimentation, the use of evidence, controls, and hypothesis testing), by proposing and critically evaluating research or experiments.
3.	Discuss, with specific examples, important factors causing the emergence of diseases.
4.	Use evidence to defend your evaluation of the threats they pose.
5.	Locate and critically assess sources of scientific information, and differentiate among primary and secondary sources.
6.	Read and analyze scientific papers and case reports, and identify the structures of these two forms of scientific communication.
7.	Demonstrate competence in several forms of writing, using logical, connected thoughts and supporting them with evidence.
8.	[a]Develop and articulate content knowledge and critical thinking in the discipline.
9.	[a]Demonstrate knowledge/understanding of audience expectations, genres, and conventions appropriate to communicating in the discipline.
10.	[a]Demonstrate the ability to compose a document of at least 2000 words through multiple aspects of writing, including brainstorming, drafting, using sources appropriately, and revising comprehensively after receiving feedback on a draft.

[a]The university WIC Program requires these Learning Outcomes in all WIC courses. MB = microbiology; BI = biology; WIC = writing intensive curriculum.

Survey design

We created the pre- and post-survey instruments to find out what the students came into the course knowing, what they left knowing, and which of the assignments were effective. The survey (Appendix 3) collected basic demographic information (class level). Survey questions were divided into three categories: 1) Experience; 2) Training and Instruction; and 3) Skills and Knowledge. Experience questions asked students to rate the number of times they had done specific types of science writing and related skills (such as scientific presentations, posters, and reference programs), from 0 ("never") to 3 ("pretty often, more than 2–3 times"). Training and Instruction questions asked how many writing courses students had taken, whether they had used university resources such as the Writing Center or workshops, and whether they had received specific training and instruction in science writing and related skills. Skills and Knowledge questions asked the students to respond to a series of statements about their writing skills, using a Likert-type scale, from 1 (strongly disagree) to 5 (strongly agree). Examples are shown in Table 2; they covered science writing skills included in the course. In addition, students were asked to respond to statements about course learning outcomes, using a Likert-type scale, from 1 (strongly disagree) to 5 (strongly agree). Examples are shown in Table 3. Finally, open-ended questions asked the students about their perceived strengths as writers, what they most wanted to improve, and what had been important to their development as writers.

The survey given at the end of the class was the same, except that for the Skills and Knowledge questions, if they felt a skill or knowledge had improved since they took the pre-test, we asked them to choose the assignments and writing activities that had helped the most. Choices included course assignments and activities (the formal writing assignments, in-class activities, lecture) and parts of the writing process (pre-writing, drafting, feedback on first draft, revising first draft, feedback on final draft).

The university Institutional Review Board approved the study. The surveys were administered online using QUALTRICS. Students took the surveys as required course assignments during the first and last weeks of the class; only those students who submitted signed consent forms (2015) or clicked "I agree" on the electronic survey consent form

TABLE 2.
Skills and Knowledge questions that showed the largest gains.

Statement	Year	Average Score Pre/Post	Average Gain	Assignment(s) That Helped the Most	Writing Activity(ies) That Helped the Most
a. I am comfortable with using a reference program such as Zotero or EndNote.	2015	2.00/3.73	1.73	Case report (8) In-class activity (7)	Pre-writing (21)
	2016	2.27/4.50	2.23	In-class activity (7) Case report (5)	Pre-writing (9) Feedback on first draft (6)
b. I understand and could explain the key components of a research proposal or a grant proposal.	2015	2.15/4.09	1.94	Grant proposal (20)	Feedback on first draft (12) Pre-writing (11)
	2016	2.23/4.31	2.08	Grant proposal (15)	Feedback on first draft (10)
c. I am familiar with the way scientific press releases are structured.	2015	2.03/4.35	2.32	Press release (22)	Pre-writing (13) Feedback on first draft (12)
	2016	1.89/4.58	2.69	Press release (13)	Feedback on first draft (9)
d. I feel confident that I could write a clear and succinct press release.	2015	2.15/4.21	2.06	Press release (22)	Feedback on first draft (16) Pre-writing (8)
	2016	1.89/4.39	2.50	Press release (20)	Feedback on first draft (12)
e. I know what a case study should contain.	2015	1.88/4.32	2.44	Case report (22)	Pre-writing (14) Feedback on first draft (12)
	2016	2.23/4.65	2.42	Case report (17)	Feedback on first draft (9)
f. I feel confident that I could write a case study from patient data or results.	2015	1.91/4.29	2.38	Case report (23)	Feedback on first draft (14) Pre-writing (10)
	2016	2.08/4.42	2.35	Case report (18)	Drafting (8) Feedback on first draft (7)
g. I recognize the term "IMRAD" and could explain it.	2015	1.26/3.56	2.30	Lecture (17) Case report (5) Position paper (5)	Pre-writing (20)
	2016	1.46/3.62	2.15	In-class activity (8) Grant proposal (5)	Pre-writing (10)
h. I know and could explain the conventions for verb tense in scientific writing.	2015	2.65/4.09	1.44	Lecture (15) Case report (7)	Pre-writing (15) Feedback on first draft (9)
	2016	2.88/4.42	1.54	Lecture (7) Position paper (7)	Drafting (7) Pre-writing (5) Feedback on first draft (5) Revising (5)
i. I could make a written argument about a scientific or health topic, and support my argument with credible evidence.	2015	N/A	<1.00	N/A	N/A
	2016	3.46/4.54	1.08	Position assignment (15)	Feedback on first draft (11)
j. I know how most peer reviewed science journal articles are organized.	2015	N/A	<1.00	N/A	N/A
	2016	3.19/4.54	1.35	In-class activity (9)	Pre-writing (9)
k. I understand and have mastered writing in the formal style used in most science writing, including, for example, writing succinctly, leaving out unnecessary verbiage, and avoiding jargon and slang.	2015	N/A	<1.00	N/A	N/A
	2016	3.00/4.31	1.31	Grant proposal (6) Position paper (5) In-class activity (5)	Feedback on first draft (9)

Skills and Knowledge questions that showed an average gain of greater than a full point between the pre- and post-surveys, along with the assignments and writing activities the students found the most helpful. Scores were on a Likert scale from 1 (strongly disagree) to 5 (strongly agree). The numbers of students who rated each element the most important are shown in parentheses, out of 34 students (2015) and 26 students (2016).

TABLE 3.
Course Content questions that showed the largest gains.

Statement	Year	Average Score Pre/Post	Average Gain	Important Course Elements and Activities
l. I am able to explain the germ theory of disease and the discovery of infectious agents.	2015	2.35/4.09	1.74	Lecture (20) Studying for exams (8)
	2016	2.88/4.54	1.65	Lecture (15) Studying for exams (5)
m. I could list the important factors causing the emergence of diseases, and give examples.	2015	3.26/4.5	1.24	Lecture (20) Studying for exams (*n*=7)
	2016	3.35/4.62	1.27	Lecture (19)
n. I could provide evidence to support my evaluation of the threats posed by emerging diseases.	2015	3.21/4.41	1.20	Lecture (*n*=14) Writing assignments (8)
	2016	3.19/4.42	1.23	Lecture (15) Writing assignments (6)
o. I could locate and critically assess sources of scientific information, and differentiate among primary and secondary sources.	2015	3.29/4.44	1.15	Writing assignments (17) Lecture (*n*=8)
	2016	3.38/4.54	1.15	Writing assignments (10)
p. I can read and analyze scientific papers and case reports, and identify the structures of these two forms of scientific communication.	2015	3.15/4.32	1.17	Writing assignments (12) Lecture (11)
	2016	3.04/4.54	1.50	Lecture (15)
q. I am competent in several forms of writing, using logical, connected thoughts and supporting them with evidence.	2015	N/A	<1.00	N/A
	2016	3.54/4.58	1.04	Writing assignments (17)

Course Content questions that show an average gain of greater than a full point between the pre- and post-surveys, along with the course elements and activities the students found the most helpful. Scores were on a Likert scale from 1 (strongly disagree) to 5 (strongly agree). In parentheses are the numbers of students who rated each element the most important, out of 34 students (2015) and 26 students (2016). N/A = not applicable

(2016) had their surveys included in the study. Most of the course participants consented to participate in the study, but some did not complete the post-survey and therefore could not be used for pre-post comparisons.

Analysis

Survey. Because the survey only sampled students in the class (there was no control group) and numbers were low, we did not statistically analyze the results. Instead, we arbitrarily considered an increase of at least a full point on our Likert scale from pre- to post-survey to represent a significant change.

RESULTS

Course description

We chose "Emerging Infectious Disease" (EID) as the subject of the course because of the societal relevance, strong student interest, importance for students entering health-related careers, and broad variety of associated topics. The three-credit class, co-listed as a Microbiology and Biology course (MB/BI 385), met twice a week, 1.5 hours/meeting, for 10 weeks during spring quarter (Syllabus, Appendix 1). Enrollment was capped at 40. The course was first offered in 2011 and assessed using the surveys in 2015 and 2016. Course prerequisites included a year of 200-level Biology; a year of Chemistry with Chemistry Labs is prerequisite to Biology.

The class covered emerging diseases from historical, evolutionary, biological, epidemiological, medical, and social perspectives. We were unable to find a textbook with broad coverage of these topics; we therefore used a variety of sources, including primary literature. In-class activities (both graded and ungraded) included reading scientific journal articles and press releases in teams, writing-to-learn activities specific to course content, short exercises on grammar and tone developed in response to student papers, focused discussions, and many more. We also visited the university library, where a librarian demonstrated databases, how to find sources, and reference programs.

Writing assignments

The overarching writing objective was to practice writing in multiple science-related genres; this was logically related to the overall emphasis within the class on the scientific method, using evidence to support an argument, controls, and hypothesis testing. Within that overall

objective, we chose four specific genres of writing: scientific press release, case study, contemporary issues/controversy paper, and grant proposal prospectus. Students were provided with detailed assignments and a rubric for each genre (Appendix 2). They received points for handing in a complete first draft of each one. The instructors returned the first drafts with significant written feedback. Students then had a week to revise and hand in a final draft, which was graded. Each student chose a specific emerging infectious disease of interest for the second through fourth assignments.

Scientific press release. To introduce the historical context of the discovery of infectious agents, we selected several important, yet short and accessible, historic papers from the 1800s (available in English in (17)). Examples included Lister's "On the antiseptic principle in the practice of surgery" (18) and Koch's "Investigations into the etiology of traumatic infective disease" (19). Small groups read and discussed one of the papers in class. Each team summarized the main points of their paper, analyzed its importance, and generated an outline to be turned in at the end of class. Students were then given an overview of scientific press releases, with examples. The assignment asked students to pretend the author of their historic paper was a *present-day scientist at our university* and rewrite the paper as a 300- to 600-word press release, following a format we gave them. This assignment provided practice in analyzing the importance of research in order to communicate it to the public; it also used an engaging team activity to introduce the students to original, historical research.

Case report. After reading several case report examples, students were asked to write a two-page case report based on a (fictional) patient suffering from an EID of the student's choice. Students researched their EID and could include whatever complications or details they desired (e.g., patient has another illness as well; patient is the first person of a particular race, age, or geographic locale to have the disease; the results of misdiagnosis), as well as figures or tables, real or fabricated, to support their claims. Students were required to supply enough information or evidence to support a logical conclusion and make it clear to the reader. A format was provided (Appendix 2). This assignment familiarized these pre-health students with case studies and provided practice in using data and evidence to support conclusions.

Controversy/Contemporary issues essay. A version of this assignment is required by our university WIC program. It provides students with the opportunity to organize and defend their thoughts about a particular issue. Students could suggest a controversy related to their chosen EID, or select from a list of medical, political, and ethical issues related to a variety of EIDs. They wrote a two- to three-page paper explaining the controversy, taking a position, and defending their position with reliable scientific evidence, referenced using an accepted format. This assignment enabled students to practice differentiating between reliable and unreliable sources.

Grant proposal prospectus. Often, the capability to do scientific research or effect change in the health sciences depends on the ability to obtain the necessary funding. For this assignment, students were asked to identify a problem or need related to their chosen EID. Posing as a representative from an organization (university, hospital or clinic, nonprofit, or the like), they were asked to write a clear, logical, compelling proposal prospectus to a funding agency (e.g., National Institutes of Health, the National Science Foundation, the Environmental Protection Agency) or a foundation (e.g., Gates Foundation, Murdoch Foundation, Nike). The proposal prospectus was two pages, single-spaced, with the following section headings: Proposal Summary, Problem Statement, Project Objectives, Project Methods or Design, Project Evaluation, Outcomes and Impact, and References. Students were required to support their background information with references, at least some of which had to be primary research papers. This assignment enabled students to practice finding scientific information, while deepening their knowledge about their chosen EID and writing logically and convincingly.

The learning outcomes for MB/BI 385 covered both writing and disciplinary content (Table 1).

Survey results

The pre-survey revealed similarities in prior experience and training between the 2015 and 2016 cohorts; the largest difference was in preparation for writing a grant proposal (Table 4). The number of previous writing classes students had taken also increased slightly in 2016. In 2015, 15% had taken one writing class, 44% had taken two, 24% had taken three, and 18% had taken more than three college writing courses. In 2016, 8% had taken one writing class, 27% had taken two, 42% had taken three, and 23% had taken more than three college writing courses.

Although grammar and conciseness were common themes students wanted to improve in their writing, they also mentioned wanting to improve their writing capabilities in science-related genres. For example, "I am excited to learn about the different writing styles related to the various methods of written communication covered in this class, like press releases and case studies, which I have yet to be exposed to"; "Being able to learn how to do the various formats used in communicating with the public: press releases, case studies, etc."; "I would like to improve my scientific formatting when it comes to writing because I have not been exposed to that style of writing very much"; "I want to improve my citing skills and scientific tone, and I would also like to learn more about the format/break down of a scientific and/or research paper (press release, grant release [sic], etc.)"; "I would like to learn more about

TABLE 4.
Students' prior experience and training.

Activity	Year	Number of Students Who Had Never Received Instruction about How to Do the Activity	Number of Students Who Had Never Done the Activity
Used a reference program	2015	27 (79%)	18 (53%)
	2016	16 (62%)	17 (65%)
Written a research proposal	2015	24 (71%)	15 (53%)
	2016	19 (73%)	12 (46%)
Written a press release	2015	32 (94%)	25 (74%)
	2016	24 (92%)	21 (81%)
Written a grant proposal	2015	26 (76%)	24 (65%)
	2016	25 (96%)	23 (88%)
Written a case report	2015	32 (94%)	22 (65%)
	2016	23 (88%)	16 (62%)

2015: n = 34; 2016: n = 26.

scientific writing and believe it to be very important to my future career."

Unsurprisingly, in the post-survey, for frequency questions (how many times have you done the following types of writing?), large gains were seen for "press release," "grant proposal," and "use of a reference program such as EndNote or Zotero" in both years. The questionnaire list did not include "case report" or "controversy paper."

The Skills and Knowledge statements that showed the largest gains are shown in Table 2. Students were also asked which assignment and which writing activity helped them the most. Assignments were the four writing assignments, in-class activities, and lecture, and the writing activities were pre-writing (notes, research, freewrite, brainstorm, etc.), drafting, feedback on first draft, revising, and feedback on final draft. The case report assignment and in-class activity (library workshop with librarian) were most beneficial assignments for becoming comfortable with using a reference program in 2015, but in 2016, the most helpful activities were pre-writing and feedback (statement a, Table 2). For specific genres, students reported benefiting most from the particular assignment that covered that genre. For the statements about "IMRAD" and verb tense (statements g and h, Table 2), lecture was the most helpful assignment. For skills and knowledge that showed gains, pre-writing activities and/or receiving feedback on their first drafts helped the most. In 2016, there were three additional areas that showed notable gains (statements i, j, and k); additional helpful activities during this year were drafting (statements f and h) and revising (statement h).

For course content, students indicated their level of agreement with statements based on course learning outcomes. The statements that showed the largest gains are shown in Table 3. In addition to indicating their level of agreement, students were asked which of the following helped them the most: lecture, reading, in-class activities, studying for exams, preparing and completing writing assignments, and feedback from teaching assistant or instructor on writing assignments. For the course and content questions specifically related to EID (statements l–n, Table 3), "lecture" was the activity that benefited students the most for both years. For the other items in this category where there were notable gains (statements o and p, Table 3), preparing for and doing the writing assignments were the most beneficial activities. In 2016, an additional item (statement q) showed a gain of >1 point, and the most helpful activity was the writing assignments.

DISCUSSION

Results of the survey and its limitations

As instructors, we struggle with the amount of time required to read and give feedback on student writing; for this reason, writing has often been dropped from the curriculum of large classes. Therefore, it was extremely rewarding to find that for the writing skills and knowledge questions where there was a large gain (Table 2), students consistently reported feedback on first drafts as one of the things that benefited them the most.

Students often reported "pre-writing" as one of the activities that benefited them the most (Table 2). We believe that they may have been referring to the writing activities that occurred in class before each assignment. Future versions of the survey will differentiate between these directed activities and other pre-writing.

There has been an increasing emphasis in the literature of science pedagogy on the interrelated concepts of "scientific literacy," "information fluency," and understanding/communicating primary literature (20–24). Our course included

specific instruction on both finding primary journal articles and reading/analyzing them. We built on these skills; by the end of the course, students were able to complete a grant pre-proposal that required researching an original question and explaining it. In these areas, students reported gains in both skills and knowledge and course content (statements g and j, Table 2; statements o and p, Table 3). However, some students may have entered the course familiar with reading primary literature. We would include a specific question about that in future.

Some questions we asked on the survey were not particularly informative. For example, few students entering the course had experience with certain genres, and therefore, unsurprisingly, many students reported that the assignment that concerned that genre helped them increase their familiarity with, and confidence in writing, that genre. This was especially true for the press release and case study, which were largely unfamiliar to the students entering the course. However, it was helpful for us to understand their relative lack of experience and training in these genres of writing before they took the course.

The class enrollment was diverse both ethnically and in terms of nationality. We did not ask whether students were first-generation college students, had parents who spoke English as a second language, or were themselves English language learners. We are considering adding these questions to a future survey.

Additional gains in 2016

In 2016, three additional Skills and Knowledge statements (statements i, j, and k) and one additional Course Content statement (statement q) showed gains of greater than one point, compared with 2015. Although we have no specific data to explain these additional gains, they may have resulted from course improvements made after analyzing the 2015 survey. We strengthened our explanations of each genre of writing and provided more examples and in-class discussions; we increased the number and length of the in-class writing instruction exercises, covering common grammatical errors and identifying colloquialisms and other issues of tone in science writing. In addition, each year, giving feedback on first drafts was shared between the instructor and a graduate teaching assistant. In 2016 the graduate teaching assistant was exceptionally competent at giving helpful feedback.

Writing to learn

The survey provided some evidence that students had learned disciplinary course content by writing. Students reported large gains in statement n, and writing assignments were one of the two important activities contributing to that gain for both years. However, although they reported significant gains in two other disciplinary areas (statements l and m), they attributed these gains primarily to lecture and studying for exams. This was in spite of the fact that there were significant writing activities in these areas, including both in-class ungraded writing and formal writing assignments. Since we require students to attend lectures and take exams, it is nice to see that they learn from those activities.

Science or science fiction?

We struggled with finding ways to teach our chosen genres of science writing to students who did not have their own data or cases to report. Our solution was to expose them to examples of each genre, and then allow them to write what was essentially fiction. We required them to back up their assertions with scientific references, and we did not allow them to make up anything (such as a treatment) that doesn't currently exist. It would be hard to measure the effectiveness of this strategy, as we did not have a control group that was writing real case studies, press releases, and grant proposals. We did observe that the students were extremely engaged by these assignments. Once they realized that they were allowed to be creative, most seemed to really enjoy the writing assignments. Compared with other writing-intensive courses we have taught, there were remarkably few complaints about what was in fact a very heavy workload of writing assignments for a ten-week course. A few students were insecure or unsure about making things up, and they tended to come to office hours to ask for approval for their ideas before handing in their drafts. Students expressed how much they liked taking the role of the expert doctor or scientist in the case study and grant proposal assignments.

CONCLUSION

The WIC program at our university promotes two different goals: writing to learn, and gaining expertise in discipline-specific writing genres. Helping students to achieve either of these goals can be challenging for university teachers. Students in the Emerging Infectious Disease class described here reported substantial gains in their skills and knowledge, both in disciplinary course content and in science writing. As an effective approach to teach science writing, both the course structure and many of the specific assignments would be useful at other institutions and for other courses.

SUPPLEMENTAL MATERIALS

Appendix 1: MB/BI 385 syllabus
Appendix 2: Writing assignments
Appendix 3: Pre- and post- writing surveys

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REFERENCES

1. American Association for the Advancement of Science. 2011. Vision and change in undergraduate biology education: a call to action. American Association for the Advancement of Science, Washington, DC.
2. Brownell S, Price J, Steinman L. 2013. A writing-intensive course improves biology undergraduates' perception and confidence of their abilities to read scientific literature and communicate science. Adv Physiol Educ 37:70–79.
3. Coil D, Wenderoth M, Cunningham M, Dirks C. 2010. Teaching the process of science: faculty perceptions and an effective methodology. CBE Life Sci Educ 9:524–535.
4. Editors. 2001. Learning to speak and write. Nature 411:1z
5. National Research Council. 2003. BIO 2010. The National Academies Press, Washington, DC.
6. Russell DR. 1990. Writing across the curriculum in historical perspective: toward a social interpretation. Coll Engl 52:52–73.
7. Adedokun O, Bessenbacher AB, Parker LC, Kirkham LL, Burgess WD. 2013. Research skills and STEM undergraduate research students' aspirations for research careers: mediating effects of research self-efficacy. J Res Sci Teach 50:940–951.
8. Clark I, Fischback R. 2008. Writing and learning in the health sciences: rhetoric, identity, genre, and performance. WAC J 19:15–28.
9. Kiefer K, Leff A. 2008. Client-based writing about science: immersing science students in real writing contexts. Across Discipl 5, http://wac.colostate.edu/atd/articles/kiefer_leff2008.cfm
10. Robnett RD, Chemers MM, Zurbriggen EL. 2015. Longitudinal associations among undergraduates' research experience, self-efficacy, and identity. J Res Sci Teach 52:847–867.
11. Quitadama IJ, Kurtz MJ. 2007. Learning to improve: using writing to increase critical thinking performance in general education biology. CBE Life Sci Educ 6:140–154.
12. Russell DR. 2002. Writing in the academic disciplines: a curricular history. Southern Illinois University, Carbondale, IL.
13. Rose M. 1985. The language of exclusion: writing instruction at the university. Coll Engl 47:341–359.
14. Bergmann L, Zepernick J. 2007. Disciplinarity and transfer: students' perceptions of learning to write. WPA J 31:124–129.
15. Craig JL, Lerner N, Poe M. 2008. Innovation across the curriculum: three case studies in teaching science and engineering communication. IEEE Trans Prof Commun 51:280–301.
16. McLeod S. 2001. The pedagogy of writing across the curriculum, p 149–164. *In* Tate G, Rupiper A, Schik K (ed), A guide to composition pedagogies. Oxford University Press, Oxford, UK.
17. Brock TD. 1999. Milestones in microbiology: 1546–1940. ASM Press, Washington, DC.
18. Lister J. 1867. On the antiseptic principle in the practice of surgery. Br Med J 2:246.
19. Koch R. 1880. Investigations into the etiology of traumatic infective disease. The New Sydenham Society, London.
20. Baram-Tsabari A, Yarden A. 2005. Text genre as a factor in the formation of scientific literacy. J Res Sci Teach 42:403–428.
21. DebBurman S. 2002. Learning how scientists work: experiential research projects to promote cell biology learning and scientific process skills. Cell Biol Educ 1:154–172
22. Fortner R. 1999. Using cooperative learning to introduce undergraduates to professional literature. J Coll Sci Teach 281:261–5.
23. Gehring K, Eastman D. 2008. Information fluency for undergraduate biology majors: applications of inquiry-based learning in a developmental biology course. CBE Life Sci Educ 7(1):54–63.
24. Klucevsek KM, Brungard AB. 2016. Information literacy in science writing: how students find, identify, and use scientific literature. Int J Sci Educ 38:2573–2595.